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(54) A glass windshield for motor vehicles with combined capabilities of sun radiation screen and image combiner.

(57) A glass article for motor vehicles, in particular a windshield, is provided with a transparent coating apt to simultaneously reduce the transmission of incident light energy and combine data relating to driving with the images of the outer environment. The transparent coating has the capacity of screening the sun radiation and sorting information deriving from an apparatus of the head-up display type.

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Th pres nt invention refers to a glass windshield which has a layer of transparent coating on its surface, providing integrated capabilities as a protective scr en against the sun, reducing radiation inside th vehicle, and as an image combiner.

At present, it is possible to see the running state of the vehicle and the driving conditions through the panel of instruments located behind the steering wheel, under the windshield.

However, in order to read the symbols showing the various data, the driver is required to lower his eyes, thus compromising driving safety. A system known in the art as "head-up display" allows the projection and thus the visualisation of certain items of control data for the vehicle in the driver's field of vision, superimposed on the external view: This system increases the degree of driving safety.

A head-up display system is formed by four basic parts:

– a source of bright light, apt to display in various forms, such as numeric, alphanumeric or graphic, the information to be shown to the driver;

– an electronic part, formed by a microprocessor system to process data and provide the information to be visualised;

– an optical system which carries the beam of light and enlarges and focusses the image at a certain distance from the eyes of the driver;

– a combiner which superimposes the image of the driving information on that of the outer environment.

Said parts are assembled and installed on a motorvehicle and constitute an integral part thereof, as does the instrument panel.

Head-up displays are known from the prior art.

In US patent 4806904 to Nissan Motor Co. there is described a head-up display which displays the speed of the vehicle on the windshield. The combiner is a sol-gel mixture of SiO2-TiO2 applied directly on the inside of the windshield, on a restricted area impinged by the light beam emitted from the source. The source of bright light is a numerical display of the VFD (vacuum flourescent display) type.

US patent 4740780 to Gec Avionics Inc. describes a head-up display capable of displaying numeric, alphanumeric and graphic messages and the combiner is a conventional untreated windshield. The source of bright light is an array of pixels formed by squared gallium phosphide LEDs, which provides a good brightness.

The publication "A holographic head-up display for automotive applications" of Flyght Dynamics Inc. on Proceedings of S.P.I.E. vol. 958 of 1988 describes a head-up display capable of visualising images on the windshield of a motor vehicle, where the combiner is formed by a volume hologram, transcribed onto dichromate-additioned gelatin on a polyesther support, and inserted, after being transcribed, on the windshield under autoclave. The hologram has no optical capacity and functions as a plane mirror. The source of bright light is formed by a halogen tungsten lamp and by a panel of transmitting liquid crystals covered by a solar filter.

European patent application n. 229876 of Yazaki Corporation describes a head-up display which displays standard information necessary to the driver, utilizing the untreated windshield as the combiner. The source of bright light is formed by an incandescence lamp placed behind a panel of transmitting liquid crystals.

The publication "A head-up display for automotive use" on Proceedings of SIB, vol. 28/3 of 1987 of Mitsubishi Electric Corp. describes a head-up display which displays the images on a windshield which has been treated with a thin layer of aluminium, evaporated on the inside surface of the same windshield. The source of bright light is formed by a fluorescent lamp emitting polarised light.

French patent application number 2569863 describes that a small area of a windshield for use in a train or a car can be coated with a TiO_2 mono-layer, to obtain a head-up display. The light transmission value in the above mentioned area is stated to be abount 55%. As a value of 55% for light transmission through a windshield is far below that required for a satisfactory transmission quality (as a comparison, the EEC standards require a value no lower than 75%), the teaching of this prior art document would appear to be contrary to using a TiO_2 mono-layer on the whole surface of a windshield for a head-up display purpose.

German patent application No. 3828137 of Central Glass Co. Ltd. describes a process to form a coating film of TiO_2 on a substrate with selected optical reflection characteristics. The TiO_2 layer is applied by a chemical process. This involves the obtaining of layers of a thickness ranging from 2900 to 3100 Å. Such thickness does not allow the use of a TiO_2 layer on the whole surface of a windshield, as it involves a light transmission value of too low a level.

European Patent application 219273 describes a multilayer transparent article having a high visibility transmittance. This document is directed to obtaining a sheet of glass having satisfactory luminous transmission characteristics with a coating suitable to an electrically heated windshield. The reflecting characteristics of this glass, however, are apparently depressed by anti-reflective ZnO layers, so that a use of the glass in a head-up display is to be excluded due to insufficient reflective capabilities.

It is furthermore known from the art that, to define the quality of a head-up display, it is necessary to consider

principally the optical charact ristics of the device and particularly the quality of the image generated by the device.

In mor detail, as quality ratio of an image the parameter $Q_r=L_i/L_f$ is defined, where L_i is the brightness of the image and L_f is the brightness of the background, that is of the outer environment. Clearly, the higher this ratio, the higher is the quality of the image, and therefore the higher are the optical characteristics of the head-up display.

It is also known that to obtain a good image brightness, that is a high value of L_i, one needs not only to have a high value of the source brightness, but also a high reflecting value of the combiner.

It is in fact possible to calculate the value of Q_r by the following formula: $Q_r=\frac{L_i}{L_f}=D\cdot\frac{T_o}{m^2}\cdot R\cdot\frac{1}{B\cdot T}$ where D is the luminance of the light source, m^2 is the background luminance, T_o is the optical transmission spectrum (except the combiner windshield), m is the total linear enlargement of the optical system, R is the reflection value of the glass, referred to the light incident on the inside of the vehicle with a certain angle of incidence, T is the value of the light transmission referred to the light coming from the outside of the vehicle, with a certain angle of incidence.

A construction of a head-up display for motor vehicles is subjected to the following restrictions. The light transmission of the windshield must not be lower than 75%, according to EEC standards, or 72% under USA standards. The combiner must provide an index of colour fidelity of over 90%. A low cost source of light must be used which is compatible with the overall cost of the motor vehicle.

Moreover, it is required that the glass for motor vehicles also serve the purpose of sun screen, both when it is used as a windshield, and when it is used as a rear or side window.

A glass is considered to function as a sun screen when it allows no more than 55% of the perpendicularly incident energy to be trasmitted into the cabin.

In view of the contrasting optical requirements and the limitations described above, it is veryfiable that, under direct solar radiation, the image results poorly visible due to the relatively low luminance of the source compared to that of the background, as a consequence of the restriction to a light source of a brightness that is neither very strong nor, in particular, very costly. Infact, although sources of light such as cathode tubes (CRT), which are capable of providing a high luminance, are commercially available, their high cost and excessive size are not compatible with the overall cost and dimensions of a motor vehicle.

Moreover, if a sheet of glass, particularly a windshield, is treated to increase its reflectance and therefore improve the luminance of the image, its transmittance of light becomes reduced below 75%, a reduction which is not commercially acceptable.

With the use of a hologram, as explained also in the prior art, there is a risk of low durability, together with the fact that it becomes difficult and costly to insert and assemble said hologram between two double curvature glass sheets.

In any case, from the prior art there does not appear to be any windshield capable of functioning with its entire surface and simultaneously as a sun screen and a combiner for a head-up display. This is nevertheless what would be sought after by motor vehicle manufacturers.

Object of the present invention is to achieve this result.

This object is achieved by a glass on which a transparent coating has been applied, formed by a one or a plurality of thin layers, chosen and placed in a manner so as to impart to the glass the capability of functioning as both an image combiner and as a sun radiation screen.

It has been surprisingly found that a glass windshield for motor vehicles with combined capabilities of sun radiation screen and image combiner can be obtained when on the whole of one of its surfaces a coating consisting of a TiO_2 layer is applied by a cathode sputtering process, the layer having a thickness from about 1200 to 1250 Å.

A similar result can be obtained in a glass windshield comprising on the whole of one of its surfaces a multilayer coating applied by a cathode sputtering process, said coating including one or two metal layers, said metal being selected from the group consisting of silver and aluminium, with the condition that said metals are different when two metal layers are provided, said metal layer having a thickness in a range from 60 to 300 Å, two inner Al_2O_3 or SiO_2 layers adjacent to the metal layer(s), each on one side thereof, and two outer TiO_2 r Al_2O_3 layers each adjacent to one of said inner layers.

In the following description the inner or outer layers will also be indicated collectively as dielectric layers.

The thickness of each of the four dielectric layers can be variable within a range from about 40 to 1500 Å. A dielectric layer on one or the other side of the metal layer(s) can have the same thickness. In this case the dielectric layers show a symmetrical arrangement with respect to the metal layer(s).

Preferably at least in one pair of adjacent dielectric layers the thickness range is from 300 to 1500 Angstrom.

D4 M
D3
D2 M
D1
glass

Indicating the four dielectric layers as D1, D2, D3, D4, numbered starting from the first layer placed over the glass substrate, and indicating the metallic layers as M, M1, an embodiment sequence of the coating of the present invention has the material forming D1 being the same as D4 and the material forming D2 being the same as D3 whereas the M layers are placed in the middle between D1 and D2 on one side and D3 and D4 on the other.

In practice, the multi-layered coating presents a combination of the following type: glass-D1-D2-M-D3-D4.

D1 and D4 are selected from TiO_2 and Al_2O_3.

D2 and D3 are selected from Al_2O_3 and SiO_2.

However Al_2O_3 cannot be selected for both the inner and the outer dielectric layers.

For a laminated windshield, the multi-layered coating is applied on one of the inner surfaces of one of th two glasses which make up the windshield, in particular on one of the surfaces which are in contact with the adhesive. For a windshield formed only by one layer of glass covered by a layer of tear-proof plastic, the coating is applied between the glass and the plastic layer.

The multi-layered coating is applied by a cathode sputtering which allows for low cost and high reliability manufacturing.

The application occurs in successive phases so as to obtain the desired number of layers and thicknesses.

In any case, the number of application phases is not less than the number of layers to be applied.

In an embodiment of the present invention, the coating apt to confer the glass with the functions of image combiner and sun radiation screen is formed by a single layer of appropriate material and thickness.

In this embodiment it has been found that a layer of TiO_2 with a preferred thickness of 120 Angstroms used as a coating, is capable of carrying out appropriately the function of image combiner and sun radiation screen.

It has been found that said layer of greater thickness affords a resistance to abrasion and chemical weathering such that it is possible for it to be used directly on an outer surface of the glass, without making it necessary to cover it with another glass or a protective layer.

As a consequence, the function of sun screen is relayed to all windows of the vehicle and, in the case of the windshield, one can advantageously obtain the function of image combiner.

It is evident, infact, that although such glass is particularly suited to carry out simultaneously both functions, nothing precludes that they be used for just one of the two functions, for example that of a sun screen.

A motor vehicle can therefore advantageously utilise the glass having a single-layer coat either as a back or side window, or as a windshield, gaining from its capacity of reducing solar irradiation. The eventual introduction in the vehicle of the head-up display will not require substitution of the windshield, as the glass is already capable of functioning as an image combiner.

The characteristics of the invention will become clearer from the description of some of the following examples, which are given only as representative and not as limitative examples.

Example 1

A clear glass sheet, produced by the float method, is suitably curved and forms one of the two sheets of a laminated windshield. On either side of said sheet, and specifically the one destined to be in contact with the adhesive layer, preferibly in PVB, the following layers are applied in succession by cathode sputtering:

TiO_2 thickness	944 Angstroms
Al_2O_3 thickness	1378 Angstroms
Al	4 Angstroms
Ag	113 Angstroms
Al_2O_3	40 Angstroms
TiO_2	163 Angstroms

After having coupled said sheet with another glass sheet using a polyvinyl-butyral adhesive layer, so that the multi-layered coating remains in between, the energy values were measured relative to the light incident from outside with an angle of incidence equal to 0º, the following results were obtained:

Light transmission (Illuminator A)	= 76.9%
Internal reflection of light (Illuminant D65)	= 11.8%
External reflection of light (Illuminant D65)	= 12.5%
Energy transmission (Moon)	= 45.6%

and for light incident from inside with an angle of incidence equal to 60º the following results were obtained:

Light transmission (Illuminant D65) = 66.4%
Reflection of light (Illuminant D65) = 21.3%

The windshield therefore satisfies both the EEC standards, and the requirement of affording a low energy transmission. At the same time the windshield has a good reflection to allow a high value of the ratio $Q_r=L_i/L_f$ which allows the use of the head-up display even under unfavourable conditions.

In particular, for a head-up display formed by: a) a phosphorus VFD light source chosen with a value of brightness equal to 10270 cd/m_2; b) an optical system which has an overall linear enlargement equal to 7.4; c) a value of the transmission spectrum of the optics of the entire device (except the windshield-combiner) equal to 0.76; and for a background luminance equal to 10000 cd/m2 and for a windshield with a working angle of 60º, the ratio of Qr is of 0.0046.

Example 2

A clear glass sheet, produced by the float method, is suitably curved and comprises one of the two glasses of a laminated windshield.

On the surface of the glass destined to be in contact with the adhesive layer, preferably PVB, the following layers are applied with the known cathode sputtering process:

TiO_2 thickness	964 Angstroms
Al_2O_3	1267 Angstroms
Ag	114 Angstroms
Al_2O_3	1267 Angstroms
TiO_2	964 Angstroms

After having carried out the assembly of the windshield the energy values were measured relative to the light incident from the outside with an angle of incidence equal to 0º, and the following results were obtained:

Light transmission (Illuminant A) = 77.2%
Internal reflection of light (Illuminant D65) = 12.9%
External reflection of light (Illuminant D65) = 13.1%
Energy transmission (Moon) = 43.4% and for light incident from the inside with an angle of incidence equal to 60º the following results werw obtained:

Light transmission (Illuminant D65) = 64.7%
Reflection of light (Illuminant D65) = 22.9%

The windshield therefore satisfies both the EEC standards and the requirement of ensuring a low energy transmission from the outside.

The windshield also has a good reflection so as to give a high value to the Qr ratio which, for a head-up display with the same characteristics as given in example 1, and for a windshield with an analogous working angle, is equal to 0.0051.

Example 3

A windshield is taken formed by a clear glass with a thickness of 2.4mm, by an adhesive PVB layer of 0.76mm and by a green glass with a thickness of 2.4mm, and has a layer of TiO2 1200 Angstroms thick deposited with the sputtering method on the last surface destined to remain to the inside of the motor vehicle.

The energy values, for light incident from outside with an angle of incidence equal to 0º, are the following:

Light transmission (Illuminant A) = 76.7%
Internal Reflection of light (Illuminant D65) = 10.9%
External reflection of light (Illuminant D65) = 12.1%
Energy Transmission (Moon) = 52.5%

and for light incident from the inside with an angle of incidence equal to 60º the following results were obtained:

Light transmission (Illuminant A)	= 71.8%
Reflection of light (Illuminant D65)	= 17.4%

The windshield therefore satisfies European standards and also ensures a low energy transmission.

At the same time the. value $Q_r = L_r/L_f$, under the same working conditions as for example 1, is equal to 0.0035 which is still a suitable value for a good quality image combiner.

Example 4 (Comparison)

The same windshield as illustrated in Example 3 was coated with TiO_2 layers of various thickness to simulate the conditions described in French patent application No. 2569863.

The following results of light transmission (LT) were obtained:

TiO_2 layer thickness (Angstrom)	LT (%)
1250	74,5
1350	69,7
1450	63,8
1550	59
1650	56,3
1750	55,9

The results show that a TiO_2 layer having a thickness higher than about 1250 Angstrom cannot be used, as the LT value is lower than the minimum allowable.

Example 5 (Comparison)

The same windshield as illustrated in Example 3 was coated with TiO_2 layers of various thickness to simulate the conditions described on Table 1 in German patent application No. 3828137.

The results are reported in the following table.

Thickness of TiO_2 layer (Angstrom)	LT (%)
2900	58,5
2950	58,5
3000	59,5
3050	60,4
3100	61,6

The LT values resulting from this test show that the windshield has too low a light transmittance to allow a use thereof on motor vehicles.

In this case the apparent inconsistance of LT values increasing as the layer thickens is explained as an effect produced by optical interference intervening due to the thickness of the TiO_2 layer approaching the wavelength of incident light (450-700 nm).

Comparison examples 4 and 5 show that no teaching could be derived from the prior art that a TiO_2 monolayer extended to the whole surface of a windshield could be a satisfactory sun radiation screen and, at th same time, an efficient image combiner.

Claims

1. A glass windshield for motor vehicles with combined capabilities of sun radiation screen and image combiner, characterized in that it comprises on the whole of one of its surfaces a coating consisting of a TiO_2 layer applied by a cathode sputtering having a thickness from about 1200 to 1250 Angstrom.

2. A glass windshield according to claim 1, in which said coating is applied on the surface of the glass exposed to the outer environment.

3. A glass windshield according to claim 1, in which said glass is a laminated glass and said coating is applied

on the inner surface of one sheet of glass adjacent to the adhesive layer of the laminated glass.

4. A glass windshield for motor vehicles with combined capabilities of sun radiation screen and image combinator, characterised in that it comprises on the whole of one of its surfaces a multi-layer coating applied by a cathode sputtering process, said coating including one or two metal layers, said metal being selected from the group consisting of silver and aluminium, with the condition that said metals are different when two metal layers are provided, said metal layer having a thickness within a range from 60 to 300 Angstrom, two inner Al_2O_3 or SiO_2 layers adjacent to the metal layer(s), each on one side thereof, and two outer TiO_2 or Al_2O_3 layers each adjacent to one of said inner layers, the thickness of each of said inner or outer layers being from 300 Angstrom to 1500 Angstrom, at least in a pair of adjacent outer and inner layers.

5. A glass windshield according to claim 4, in which said adjacent inner and outer layers have a thickness showing a symmetrical arrangement with respect to said metal layer(s).

6. A glass windshield according to claim 4 in which each layer in one pair of adjacent inner and outer layers has a thickness from 40 to 200 Angstrom.

7. A glass windshield according to claim 4, in which said glass is a laminated glass and said multi-layer coating is applied between the two sheets of glass which form the laminated glass.